

# Uncertainty, Instability, and Irreversible Investment

Theory, Evidence, and  
Lessons for Africa

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Instability and uncertainty are important factors in Africa's poor investment record over the past two decades.

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## Summary findings

A recent (but rapidly growing) literature has focused on how uncertainty and instability affect the adoption of fixed investment projects. That literature shows that if fixed investment projects are costly or impossible to reverse, uncertainty can become a powerful deterrent to investment.

Serven reviews the literature on irreversible investment to identify the implications for macroeconomic policy and to gauge the practical importance, especially for Sub-

Saharan Africa, of the link between uncertainty and investment.

He presents empirical evidence on the negative association between investment performance and measures of instability, using cross-section time-series data. That evidence suggests that instability and uncertainty are important factors in Africa's poor investment record over the last two decades.

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This paper — a product of the Macroeconomics & Growth Division, Policy Research Department — is part of a larger effort in the Department to understand the determinants of private investment. Copies of this paper are available free from the World Bank, 1818 H Street NW, Washington DC 20433-0001. Please contact Emily Khine, room N11-061x, telephone 202-473-7471, fax 202-522-3518, internet address [kkhine@worldbank.org](mailto:kkhine@worldbank.org). February 1997. (44 pages)

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**Uncertainty, Instability, and Irreversible Investment:  
Theory, Evidence, and Lessons for Africa**

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## 1. Introduction

Many people would agree with the view that uncertainty and instability can be serious obstacles to fixed investment decisions. Casual empiricism also suggests that most fixed investments are more easily done than undone. Until recently, however, conventional investment theory has paid little attention to these two facts and, more specifically, to the links between them.

Those links are precisely the focus of a recent, but rapidly growing, investment literature. This literature has shown that if investment is costly, or impossible, to reverse, investors have an incentive to postpone commitment and wait for new information in order to avoid costly mistakes. Moreover, this "value of waiting" can be quite considerable, especially in highly uncertain environments. As a consequence, uncertainty can become a powerful investment deterrent -- a conclusion that seems to be supported by mounting empirical evidence and has important policy implications.

This paper has two objectives. First, it summarizes the recent analytical and empirical literature on irreversible investment, focusing in particular on what the theory implies -- and what it does not -- for the relationship between uncertainty and investment, and drawing its consequences for macroeconomic policy.

The second objective of the paper is to gauge the relevance of the uncertainty-investment link for Sub-Saharan Africa. This seems an important task in the context of the current policy discussion on the causes of Africa's dismal growth performance over the last two decades.<sup>1</sup> The resumption of sustained growth in Africa will undoubtedly require a substantial investment expansion -- that will have to come primarily from the private sector.<sup>2</sup>

Yet the recent investment literature suggests that the economic and political instability suffered by many African countries can pose a formidable obstacle to the private investment takeoff. To assess this question, the paper presents some preliminary empirical evidence on the role of uncertainty and instability as investment deterrents, both in Africa

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<sup>1</sup> For recent analyses see Easterly and Levine (1996), Hadjimichael *et. al.* (1995) and World Bank (1994).

<sup>2</sup> See Elbadawi (1995) for a discussion of Africa's broad policy priorities.

and in other developing regions. In this regard, the paper complements and extends some recent empirical work on the determinants of private investment in Africa. From this analysis, and drawing from the findings of the irreversibility literature, the paper derives some policy lessons for reviving investment in Africa.

The paper is organized as follows. Section 2 presents a brief overview of the theoretical literature on investment irreversibility. Because the analytics of irreversible investment quickly become cumbersome, the discussion is organized around some simple examples illustrating the main ideas. Next, section 3 summarizes a number of extensions and empirical applications of the basic analytical framework, as well as the related empirical literature on uncertainty and investment. Section 4 focuses on the empirical links between instability and private investment in Sub Saharan Africa, using a cross-regional comparative perspective. Finally, section 5 concludes.

## **2. Irreversible investment: an analytical overview**

Over the last three decades, conventional investment theory has relied on two essentially equivalent approaches. One is the cost-of-capital view of Jorgenson (1963), according to which the firm's desired stock of capital is found by equating the marginal product and the user cost. The other formulation, due to Tobin (1969), focuses on the capitalized value of the marginal unit of capital relative to its replacement cost, a ratio known as  $q$ . In either approach, costs of adjustment -- typically assumed convex -- need to be assumed to transform an otherwise static problem to a dynamic setting involving expectations about the future.

The empirical failure of these traditional views of investment<sup>3</sup>, and the lack of realism of some of their foundations -- notably the assumption of convex adjustment costs -- have led to the emergence in the last decade of a new view of investment, that emphasizes three important features of most investment decisions overlooked by the conventional approach (Dixit and Pindyck, 1994). First, most fixed capital investments are partly or completely *irreversible*: the initial cost of investment is at least partially sunk -- it

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<sup>3</sup> See e.g. Abel and Blanchard (1986).

cannot be recovered completely by selling the capital once it has been put in place<sup>4</sup>. Second, investment decisions have to face *uncertainty* about their future rewards -- the best investors can do is attach probabilities to the possible outcomes. Third, investors can control the *timing* of investment, and postpone it in order to acquire more information about the future.

These three facts conform the so-called *option approach* that views an investment opportunity as an option to purchase an asset at different points in time. The optimal investment policy balances the value of waiting for new information with the cost of postponing the investment in terms of forgone returns. When a firm makes an irreversible investment expenditure, it kills its option to wait for new information that might affect the desirability of the investment. To take account of this fact, the standard net-present-value investment rule (invest when the anticipated return on the additional capital equals its purchase and installation cost) must be modified: the anticipated return must *exceed* the purchase and installation cost by an amount equal to the value of keeping the option alive.<sup>5</sup> The recent literature has shown that the option value of waiting can be considerable, especially in a highly uncertain environment. As a consequence, uncertainty can become a powerful deterrent even for risk-neutral investors.

While these ideas may seem intuitive, the analytics of irreversible investment are far from trivial. Thus, the discussion in this section is organized around two simple examples introducing the basic concepts. The interested reader is referred to the comprehensive discussion in Dixit and Pindyck (1994).

### *The single-project, two-period case*

Consider a simple two-period example in which a risk-neutral firm has to decide whether to invest in an irreversible project whose purchase cost is  $p_K$  and whose future

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<sup>4</sup> Investment irreversibility was first studied by Arrow (1968) in a deterministic context. He showed that optimal irreversible investment is characterized by alternating periods of positive gross investment and zero gross investment; during the latter periods, the shadow value of capital is less than its user cost.

<sup>5</sup> The precise way in which the "naive" net present value rule needs to be modified is discussed by Abel *et. al.* (1996).

return is uncertain -- due perhaps to uncertainty about the price of the project's output, about market demand, or other similar causes. More specifically, assume that if investment takes place now, the project will yield a *known* return  $R_0$  at the end of this year, and then an uncertain return  $R$  in each succeeding year. With the information available today, the expected value of the future return is  $E_0[R]$ . Hence the present value of the anticipated stream of cash flows is

$$\begin{aligned} V_0 &\equiv -p_K + \frac{1}{1+r} R_0 + \left[ \frac{1}{1+r} \right]^2 \sum_{i=0}^{\infty} (1+r)^{-i} E_0[R] \\ &= -p_K + (1+r)^{-1} [R_0 + (1/r) E_0[R]] \end{aligned}$$

where  $r$  is the discount rate -- or the real rate of return on the alternative asset. Naive application of the net present value criterion would recommend undertaking the project if  $V_0 > 0$ , which can be conveniently rewritten as:<sup>6</sup>

$$(R_0 - rp_K) + \frac{(E_0[R] - rp_K)}{r} > 0 \quad (1)$$

Note that, absent depreciation,  $rp_K$  is Jorgenson's (1963) user cost of capital. If investment were fully reversible, then the future would not matter, and the optimal decision would be to invest now if and only if  $R_0 > rp_K$  -- i.e., if the *current* return exceeds the user cost of capital -- because the decision can always be undone next period should events turn out adverse.

However, even if (1) holds *ex-ante*, the firm may regret *ex-post* having undertaken the project. This situation can arise if there is a chance that  $R < rp_K$ , so that with some probability the future return will fall short of the cost of capital. In such case, the firm would find itself committed to an unprofitable project. When such possibility exists, and the firm can defer the investment to learn more about the future return -- perhaps by

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<sup>6</sup> Observe that equation (1) can also be viewed as a version of the  $q$  approach: invest if the present discounted value of the anticipated returns exceeds the purchase cost of the project -- i.e., if Tobin's  $q$  is greater than unity. In this context Tobin's  $q$  is just  $q \equiv \frac{(1+r)^{-1} [R_0 + (1/r) E_0[R]]}{P_K}$ , where the numerator measures the present discounted value of future profits from the project, and the denominator is its purchase cost.



observing the trajectory of output prices or demand determinants --, the decision rule given by (1) is incorrect. The reason is that it may pay to wait for more information before making an irreversible commitment.

As an extreme example, assume that uncertainty will completely vanish next period, so that the future return will remain constant forever at whatever value is realized next year. In such case, consider a strategy involving no action this year -- and therefore no cash flows -- and undertaking the project next year only if the return turns out to exceed the user cost of capital, but not otherwise. The anticipated stream of cash flows from this strategy is

$$V_1 \equiv \Pr[R > rp_K] \left\{ \frac{1}{1+r} (-p_K) + \left[ \frac{1}{1+r} \right]^2 \sum_{i=0}^{\infty} (1+r)^{-i} E_0[R|R > rp_K] \right\}$$

Notice that the entire expression is multiplied by the probability that the project's return will turn out to exceed the user cost of capital, since only in that case will the investment be made next year<sup>7</sup>. We can compare the two strategies by computing<sup>8</sup>

$$V_1 - V_0 = \left( \frac{1}{1+r} \right) \left[ \Pr[R < rp_K] \frac{E_0[rp_K - R|R < rp_K]}{r} - (R_0 - rp_K) \right] \quad (2)$$

It pays to invest immediately if this expression is negative, which is equivalent to the requirement

$$(R_0 - rp_K) > \Pr[R < rp_K] \frac{E_0[rp_K - R|R < rp_K]}{r} \quad (3)$$

This condition simply compares the cost of waiting -- the current period net return  $(R_0 - rp_K)$  forgone by not investing -- with the value of waiting, given by the irreversible mistake that would be revealed tomorrow should future project returns fall short of the user cost of capital (i.e.,  $R < rp_K$ ). The expected present value of such mistake is measured by the right-hand side of (3): the mistake is made with probability  $\Pr[R < rp_K]$ ; its expected per-period size, given today's information, is  $E_0[rp_K - R|R < rp_K]$ , and since it

<sup>7</sup> Obviously, it never pays to wait and then invest when the return turns out to be below  $rp_K$ .

<sup>8</sup> Recall that  $E_0[R] \equiv \Pr[R > rp_K] E_0[R|R > rp_K] + \Pr[R \leq rp_K] E_0[R|R \leq rp_K]$ .

accrues every period into the indefinite future, it has to be multiplied by  $(1/r)$  to transform it to present value terms. It pays to invest immediately only if the first-period return *exceeds* the conventional user cost of capital by a margin large enough to compensate for the possible irreversible mistake -- i.e., if the cost of waiting outweighs the value of waiting.

The remarkable feature of (3) is that the "good news", represented by a future realization of  $R$  above  $rp_K$ , is completely *irrelevant* for the investment threshold. This is the *bad news principle* first noted by Bernanke (1983): only the expected severity of future bad news matters for the decision whether to invest today; potential good news does not matter at all. The intuitive reason for this asymmetry is that the option to wait has no value in states in which adopting the investment would have been the right decision -- it is only valuable in those states in which early investment would have been regretted. This *option value of waiting* equals the maximum of  $V_I - V_0$  and 0. If  $V_I \leq V_0$  the option has no value, and the optimal decision is to proceed immediately with the investment.

Even with moderate amounts of uncertainty, however, the value of the option can be quite substantial. This can be easily seen by computing the premium above the user cost of capital that an irreversible project must offer for investors to give up their option to wait. Consider a simple example of an irreversible project that with probability .10 will "fail" -- in the sense of yielding an annual return 2 percentage points below the discount rate  $r$  -- and with probability .90 will "succeed". Letting  $p_K=1$  and  $r=.04$ , we can ask: what immediate return  $R_0$  must the project offer for a risk-neutral investor to undertake it? Simple calculations using (3) above show that  $R_0$  must be at least 9 percent -- i.e., *five* percentage points above the cost of capital -- for a rational investor to adopt it.

The key implication of the bad news principle is that *any* spread of the distribution of future returns, whether mean preserving or not, which increases *downside* uncertainty, raises the option value of waiting and therefore tends to depress investment.<sup>9</sup> In the

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<sup>9</sup> Some exceptions to this rule should be noted, however. If investment is at least partially reversible, and the cost of investing tomorrow is relatively high (i.e.,  $p_K$  is rising over time), the asymmetry could be reversed into a "good news" principle, whereby only *upside* uncertainty would matter, and its effect would be to hasten investment (Abel *et. al.* 1996). Likewise, if the opportunity cost of waiting  $R_0$  is uncertain rather than known -- as would be the case for investment projects subject to completion lags -- and the firm can abandon the project (at a cost) in the future, then again higher

preceding example, assume that we reduce the project's return in the adverse scenario by 1 percent, so that now it falls short of  $r$  by 3 percent. [We can also raise the returns in the favorable scenario as much as we want, but these are irrelevant.] With all the other parameters unchanged,  $R_0$  now must be at least *11 percent!* Two extra points of premium are now required, because the irreversible mistake has become larger.<sup>10</sup>

### *Selection among multiple projects*

So far we have assumed that only one investment project was available to the firm. However, an important corollary of the bad news principle concerns the selection among multiple irreversible investment projects: any events that threaten to alter the profitability ranking of the different projects -- even if they increase the absolute returns to *all* projects -- tend to reduce investment.

Another example may serve to illustrate this point. Consider a firm deciding between two projects, both of which require an investment equal to 1 ( $= p_K$ ). The first one uses labor, and therefore its future return depends on the evolution of the real wage. Today the real wage equals  $w_0$ ; from next year on, it can rise to a high level  $w^H$  with probability  $(1-p)$  or fall to a low level  $w^L$  with probability  $p$ . The project's annual return equals 1 minus the real wage, so that the net present value of its cash flows is

$$V_0(\text{project 1}) = -1 + (1+r)^{-1} \left[ (1-w_0) + (1/r) \left\{ p(1-w^L) + (1-p)(1-w^H) \right\} \right]$$

and it is assumed that  $(1-w^L) > (1-w^H) > r$ , and  $(1-w_0) > r$ , so that the project is profitable in either scenario. By contrast, the second project uses no labor and therefore its return is independent of the real wage. Assume the annual return equals  $a$ . Then:

$$V_0(\text{project 2}) = -1 + (1+r)^{-1} [a + (1/r)a] = -1 + (a/r)$$

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uncertainty could hasten investment, by making extreme favorable realizations of  $R_0$  more likely (extreme adverse realizations would also become more likely, but the firm could avoid their impact by shutting down the project) and thus raising the cost of waiting along with the value of waiting (see Bar-Ilan and Strange 1996).

<sup>10</sup> However, these large premia are consistent with the high "hurdle rates" applied in practice by firm managers when assessing investment projects.

Assume that at first  $a < (1-w^H)$ . The second project is always less profitable than the first one, and the optimal strategy is to undertake project 1 immediately. Suppose, however, that a technical improvement causes  $a$  to rise to  $1-w^H < a < 1-w^L$ , so that with high wages project 2 becomes more profitable than project 1. Intuitively, since the profitability of at least one project has risen, investment should be encouraged. But this is not the case, because now it may be better to wait until next period, and then adopt project 1 if wages turn out low and project 2 if they are high. This strategy would yield:

$$V_1 \equiv \frac{1}{1+r}(-1) + \frac{1}{r(1+r)} \{p(1-w^L) + (1-p)a\}$$

It is easy to verify that waiting becomes the optimal strategy if

$$(1-w_0-r) < \frac{(1-p)(a-[1-w^H])}{r}$$

$$(a-r) < \frac{p(1-w^L-a)}{r}$$

If both inequalities hold, an increase in the profitability of project 2, without any decline in the profitability of project 1, actually *lowers* investment, as the firm now prefers to wait until next period in order to avoid the irreversible mistake of having chosen what could turn out to be the ‘bad’ project -- a problem that previously could not arise because project 1 was superior in every possible scenario.

### ***Incremental investment***

The discussion above focused on discrete investment decisions, i.e., the adoption of specific projects of given size. In reality, however, firms typically operate many projects, and their investment decisions can be better viewed as determining the path of their total capital stock.

The optimal irreversible investment policy of a firm facing uncertainty was first analyzed by Bertola (1988) and Pindyck (1988). They considered the case of a firm possessing a decreasing-returns technology and facing a downward-sloping demand schedule. Under such assumptions, successive marginal increments to the capital stock can be regarded as distinct ‘projects’, each of which contributes its marginal product

independently of the others. Hence, similarly to the above discussion, it is possible to find an investment threshold for each project, and then sum over the different projects to obtain the firm's desired capacity expansion. As before, the profitability threshold that must be reached for investment to take place exceeds the user cost of capital as conventionally computed, and rises with the degree of uncertainty faced by the firm.

The characterization of the investment threshold, and its relation with the existing degree of uncertainty, have been recently re-examined in a more general setting by Abel and Eberly (1994, 1995a). They present a framework in which downward adjustment of the capital stock is possible, but more costly than upward adjustment, and allow also for the existence of convex adjustment costs to investment similar to those assumed by the conventional investment literature.<sup>11</sup> Hence, the standard  $q$  investment model (see e.g., Hayashi 1982) can be viewed as a particular case of this general setting.

In this framework, the optimal investment strategy is a *two-trigger* policy that can be expressed in terms of Tobin's marginal  $q$  -- defined as the addition to the value of the firm resulting from an additional unit of capital. If  $q$  exceeds a certain upper threshold  $q^+$ , positive gross investment occurs. In turn, if  $q$  falls below a lower threshold  $q^-$ , *negative* gross investment takes place -- i.e., the firm sells part of its capital stock. Between  $q^+$  and  $q^-$ , investment equals zero.

This optimal policy can be illustrated with the help of Figure 1, adapted from Dixit and Pindyck (1994), which shows the marginal cost of investment as a function of investment. In the absence of fixed costs, the total cost of investment (disinvestment) equals the capital purchase (sale) cost (revenue) plus the standard convex adjustment cost. In general, the slope of the latter may differ for positive and negative investment. In such framework, the upper threshold  $q^+$  is equal to the purchase price of capital, denoted  $p_K^+$ , plus the marginal adjustment cost to positive investment evaluated at zero investment, denoted  $C'(0^+)$ . Likewise, the lower threshold  $q^-$  equals the sale price of capital  $p_K^-$  plus the marginal adjustment cost to disinvestment evaluated at zero,  $C'(0^-)$ .

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<sup>11</sup> They also allow for "flow" fixed costs -- i.e., costs whose magnitude is independent of the volume of investment but dependent on the length of the period over which investment takes place. This contrasts with "stock" fixed costs, which are independent of this latter factor as well. Stock fixed costs lead to "lumpy" investment, as analyzed by Caballero and Leahy (1996).

If  $q$  is above  $q^+$ , investment is positive, and if  $q$  is below  $q^-$ , investment is negative. Between  $q^+$  and  $q^-$  there is a range of inaction. Such range exists as long as (i)  $p_K^+ > p_K^-$ , so that capital can be sold only at a loss; or (ii) marginal adjustment costs are steeper for positive than for negative investment, i.e.,  $C'(0^+) > C'(0^-)$ ; or (iii) there are *fixed* costs to investment (ignored in the figure). Moreover, investment is determined exclusively by Tobin's (marginal)  $q$ , by  $p_K^+$  and  $p_K^-$ , and by the parameters characterizing the adjustment cost function.<sup>12</sup>

If convex adjustment costs are ruled out, investment occurs in episodic bursts. The firm's optimal policy involves purchasing or selling capital to keep its marginal revenue product between an upper and a lower bound,  $\pi_K^+$  and  $\pi_K^-$  (Abel and Eberly, 1995a). When the marginal revenue product reaches either of these bounds, a burst of investment (positive or negative) occurs to equalize the actual and optimal capital stocks. In turn, if the marginal revenue product is between both bounds, no action is taken (see Figure 2). These bounds can be interpreted as the correctly-measured user cost of capital relevant for investment and disinvestment, respectively. Specifically,  $\pi_K^+$  (respectively,  $\pi_K^-$ ) exceeds (falls short of) the conventionally-defined user cost of capital, that would equal  $(r+\delta)p_K^+$  (or  $(r+\delta)p_K^-$  for disinvestments). Most importantly, higher uncertainty increases the wedge between the upper and lower bounds, and thus the range of inaction.

### *Uncertainty and investment*

The models just described characterize the critical threshold that must be reached by the marginal profitability of capital in order for investment to occur. They predict that if volatility increases the investment threshold will also rise -- firms will be more reluctant to invest to avoid getting caught with too much capital, should the future turn out worse than expected. By contrast, if the future turns out better than expected, the firm can just add more capital as needed.

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<sup>12</sup> If  $C'(0^-) < 0$  and/or fixed costs exist, it is possible that  $q^- < 0$ , in which case negative investment will never be observed, as implied by the strict irreversibility hypothesis.

However, the models do *not* characterize the impact of volatility on investment. Such impact depends in addition on the effects of volatility on the marginal profitability of capital. For example, if the marginal revenue product of capital is a convex function of the variable whose evolution is uncertain (e.g., the output price or the real wage), then higher uncertainty *raises* expected profitability and, *ceteris paribus*, the desired capital stock (Hartman 1972, Abel 1983).<sup>13</sup> This effect goes in opposite direction to the threshold effect above, and the net result is in general indeterminate. As shown by Caballero (1991), decreasing returns to scale and/or imperfect competition -- either of which makes the marginal revenue product of capital a decreasing function of the capital stock -- make it more likely that the threshold effect will dominate, so that higher uncertainty leads to lower investment.<sup>14</sup>

A second difficulty is that, even if the threshold effect dominates so that irreversibility and uncertainty reduce investment (or the desired capital stock) ex-ante in the short run, little can be said on their long-run impact (Bertola and Caballero, 1994). Higher degrees of irreversibility and/or uncertainty make it more likely that firms will ex-post find themselves holding too much capital. This 'hangover effect' (Abel and Eberly, 1995b) tends to increase the long-run capital stock (and other measures like the investment/output ratio) above the level that would have prevailed with less irreversibility or less uncertainty.<sup>15</sup>

However, some inferences about the impact of uncertainty on investment can still be drawn from these models. In particular, *temporary* increases in uncertainty should

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<sup>13</sup> A familiar scenario has capital as the only fixed factor, while other productive inputs (e.g., labor) can be costlessly adjusted in the face of changing prices. Price shocks lead the firm to change the optimal capital/labor mix, thus causing the marginal revenue product of capital to rise more (or fall less) than output prices -- i.e., the former will be a convex function of the latter.

<sup>14</sup> In the special case of constant returns to scale and perfect competition, the opposite result obtains (Caballero, 1991). The reason is that the marginal revenue product of capital (whether current or future) does not depend on the capital stock, and therefore the firm is no more reluctant to invest under irreversibility than it would be with perfect reversibility. However, the effect of *aggregate* (as opposed to *idiosyncratic*) uncertainty on investment of a competitive *industry* can still be negative (Caballero and Pindyck, 1992).

<sup>15</sup> The lack of a more robust linkage between uncertainty and investment through irreversibility has led some researchers to look for alternative rationalizations. One example is the "disappointment aversion" analyzed by Aizenman and Marion (1995).

reduce investment, at least in the short run, because fewer projects will exceed the higher investment threshold resulting from increased volatility.

### ***Aggregation***

All the above discussion has been concerned with the investment decision of a single firm. From the macroeconomic point of view, however, the question of primary interest is the impact of irreversibility and uncertainty on aggregate investment. Yet it is obvious that one cannot just translate mechanically the above microeconomic results to aggregate investment. In reality, we never observe the spells of zero aggregate investment that should arise if *all* firms in the economy faced the irreversibility constraint -- or were all at once in the range of inaction identified in microeconomic models. Instead, aggregate investment displays considerable smoothness and inertia.<sup>16</sup>

To assess the role of irreversibility in aggregate investment it is therefore essential to take explicitly into consideration the heterogeneity of individual firms' investment decisions. Each firm adjusts its capital stock when profitability exceeds a firm-specific threshold, reflecting managerial abilities, output market conditions, and other idiosyncratic factors. At any given time, some firms may be close to their trigger points and others far from them. Firms may be subject to both aggregate shocks, which tend to push all firms above or below their investment trigger points, and specific shocks, which push different firms in different directions. Thus the response of aggregate investment to an aggregate shock may display substantial inertia, as different microeconomic units reach their investment thresholds at different times -- even though each firm's policy may involve a discrete investment burst once its idiosyncratic threshold has been reached.

However, aggregation of individual firms' investment policies is not easy because, as we saw above, under irreversibility such policies are nonlinear. Thus, the impact of a given economy-wide shock on aggregate investment depends, for example, on how many individual firms are within their inaction ranges, how far they are from their trigger points, and how important are idiosyncratic shocks relative to aggregate shocks.

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<sup>16</sup> Indeed, the original rationale behind the standard convex adjustment-cost approach to investment was precisely to replicate these two empirical facts.



Bertola and Caballero (1994) have recently explored the implications of irreversibility for aggregate investment in a model in which individual firms' investment proceeds in discontinuous bursts. Individual investments are not synchronized, and firms are subject to idiosyncratic uncertainty in addition to aggregate uncertainty. As a result, aggregate investment shows smoothness. A favorable aggregate disturbance (e.g., a fall in the price of capital goods) may have a very small effect on aggregate investment if many firms are far below their threshold for positive investment, and may take a long time to develop its full impact, which depends on initial conditions -- i.e., on firms' original situation relative to their respective investment thresholds.

### **3. Extensions and empirical applications**

The basic models of irreversible investment summarized in the previous section focused on output demand and/or prices as the basic sources of uncertainty. It should be clear, however, that uncertainty arising from other sources can have exactly the same effect on irreversible investment decisions, as an expanding literature has underscored. For example, Ingersoll and Ross (1992) examine the consequences of interest rate uncertainty in a context in which future investment returns are known. They show that interest rate uncertainty creates a value of waiting; moreover, a decline in interest rates accompanied by an increase in their volatility can actually reduce investment (see also Tornell 1990). Thus, to promote investment the stability of interest rates might be more important than their level.

Likewise, Dixit (1989) and Baldwin and Krugman (1989) focused on real exchange rate uncertainty. They showed that sunk costs of entry may discourage firms from moving into export activities that would appear profitable in light of current real exchange rate levels.

Uncertainty may also be policy-induced. The case of uncertain tax policy is addressed by Hassett and Metcalf (1994). They show that an increase in the volatility of taxes (specifically, an investment tax credit) has the usual effect of raising the hurdle rate required by investors to undertake irreversible projects. However, they also conclude that

the overall impact on investment generally depends on the specific form taken by tax uncertainty (see Hubbard 1994 for further discussion).

From the policy viewpoint, an extremely important form of uncertainty faced by investors is the imperfect credibility of policy reforms. Investment-friendly reforms typically raise expected returns, but may also increase uncertainty if investors believe that the reform measures could be reversed. In such context, investors' perceptions about the probability of reversal become a key determinant of the investment response. The reason is of course that the possibility of policy reversal creates a value of waiting for investors facing irreversible projects. Thus, lack of confidence can be reflected in a weak and delayed investment response, as it may take time for investors to become convinced that the reforms will be sustained. This pattern is in fact consistent with the "investment pause" often observed in the aftermath of adjustment programs in developing countries (see World Bank 1993).

These issues are explored by Rodrik (1991) using a model in which investment involves sunk costs of entry and exit. He shows that a reform favorable to capital, but regarded as less than fully credible, will fail to trigger off an investment response unless the return on capital becomes high enough to compensate investors for the losses they would incur should the reversal take place. Following Rodrik, this can be illustrated with the help of equation (3) above, modified to let  $R_0 - t$  the return that would prevail if the reform were reversed (forever), where  $t$  can be interpreted as a tax on capital that would be re-imposed following reversal (and thus can be viewed as the "size" of the reversal). Assuming that the reversal happens with probability  $1-p$ , and taking also  $p_K=1$ , (3) can be rearranged to yield:

$$(R_0 - r) > \frac{t}{1 + \frac{r}{1-p}} \quad (3')$$

This expression characterizes the premium over the risk-free rate that investors have to be offered in compensation for the possibility of policy reversal. As noted by Rodrik, the premium can be quite substantial even when credibility is rather high (see also Dornbusch 1990). For example, if the real discount rate  $r$  equals 3 percent, a 15 percent

probability that reform will collapse would require the current return  $R_0$  to exceed  $r$  by over 80 percent of the value of  $t$  -- even though the probability of reversal is only 15 percent ! Thus, if  $t$  is 5 percent, say, the return  $R_0$  will have to be at least 9 percent (i.e., three times the interest rate) for investors to be willing to undertake irreversible projects.

Similar qualitative conclusions are reached by van Wijnbergen (1985), who considers the case of a trade reform suspected to be only temporary. He shows that the result can be a decline in investment in *both* the traded and non-traded goods sectors, as investors wait for additional information and thus avoid irreversible commitment to any particular industry -- a conclusion that can be easily understood recalling our earlier discussion of the selection among multiple irreversible projects.

Thus, the perception that reforms may be unsustainable can have a very adverse impact on investment. However, it is important to recognize that the sustainability of reform is ultimately endogenous, and depends largely on the response of the private sector. Lack of a sufficient investment response can delay growth, increase social hardship, and ultimately force the reversal of the reforms, confirming investors' initial skepticism.

This endogeneity is formally investigated by Laban (1991) in a model in which investors can repatriate flight capital following a stabilization that lacks full credibility. Investors face a choice between irreversible fixed investment and liquid assets, and the latter have an option value, due to the lack of confidence in the permanence of the stabilization. At the same time, however, the sustainability of the program depends on its ability to generate sufficient fixed investment -- a mechanism ignored by the individual investor. Laban shows that in these circumstances the outcome of the stabilization is generally indeterminate, as investors' expectations can become self-fulfilling: pessimism leads to insufficient fixed investment and thus to collapse of the stabilization program, while optimism leads to the opposite result. The underlying reason is that the combination of investment irreversibility and strategic complementarity of investors' decisions creates an externality, that drives a wedge between the social and private returns to investment.

### ***Empirical studies***

The empirical literature on irreversible investment has lagged far behind the theoretical developments. The main reason is of course the analytical complexity of irreversible investment models, which typically involve nonlinear investment rules whose empirical estimation is computationally cumbersome. As a result, most of the existing empirical studies of the impact of irreversibility adopt a reduced-form approach.

There are some exceptions, however. At the microeconomic level, an important recent study by Caballero, Engel and Haltiwanger (1995), using a large sample of U.S. plant-level data, uncovers strong evidence of irreversibility. Using a simple structural model of irreversible investment, the authors find that adjustment of the capital stock to its optimal level is highly nonlinear, and typically much faster for upward than for downward movements in the capital stock -- as should be the case if retiring capital is more costly than acquiring it.

Leahy and Whited (1995) use the same type of data in a reduced-form empirical approach. They note that in most models of irreversible investment the effect of uncertainty on investment operates through Tobin's (marginal)  $q$ . If such models are an accurate description of reality, uncertainty should have a negative impact on  $q$  but no *independent* impact on investment, once  $q$  has been controlled for<sup>17</sup>. Their empirical results using U.S. data provide support for this view. Likewise, recent empirical work by Nilsen and Schiantarelli (1996) using Norwegian plant-level data in a reduced-form framework also uncovers evidence of irreversibility and lumpiness in investment.

At the aggregate level, in turn, Bertola and Caballero (1994) have implemented empirically a structural model that follows explicitly from the aggregation of individual firms' irreversible investment rules. The resulting specification of aggregate investment is able to capture the key features of the U.S. data. Caballero (1993) applies a similar approach to developing country data, with equally promising results. These two studies illustrate the asymmetric response of aggregate investment to positive and negative

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<sup>17</sup> Strictly speaking, this is true as long as investment does not involve (stock) fixed costs. In the opposite case, investment is lumpy, and bears no monotonic relation to marginal  $q$ . See Caballero and Leahy (1996).

shocks, and its strong dependence on initial conditions: after a deep recession, for example, many firms are likely to be well below their investment thresholds, and therefore the responsiveness of aggregate investment to positive incentive changes can be very limited.

A different approach is followed by Pindyck and Solimano (1993) to test for the effects of uncertainty on aggregate (and also sectoral) investment (see also Caballero and Pindyck 1992). As noted earlier, the long-run impact of uncertainty on investment is ambiguous on theoretical grounds, but its impact on the profitability threshold above which firms will invest is unambiguous. Thus, a test of the importance of irreversibility can be performed by investigating the dependence of that threshold on measures of uncertainty. Using panel data for industrial and developing countries, such empirical exercise reveals a moderate impact of the variability of the marginal profitability of capital on the investment threshold. Pindyck and Solimano also find that inflation appears to be a major cause of volatility and is strongly negatively related to measures of investment performance -- thus suggesting that control of inflation can have a big investment payoff. Recently, Levy Yeyati (1996) has proposed a reinterpretation of this result in the context of a structural model of irreversibility that highlights the role of current inflation as predictor of the future price volatility faced by investors. He offers some empirical evidence in support of this view.

A recent empirical study by Ibarra (1995) is one of the few to focus on the effects of credibility. He explores the case of the Mexican trade liberalization of the late 1980s, which was accompanied by a substantial private investment slump. Drawing from cross-country evidence, he estimates empirically the path of the probability of reform reversal, and shows that it can contribute to explain a substantial portion of the observed investment slowdown.

These findings are closely related to those reported by a growing empirical literature that examines the contribution of simple measures of uncertainty or volatility to explaining private investment performance, typically in the framework of otherwise conventional empirical specifications. Along these lines, Sérvén and Solimano (1993b) find a significant negative impact of inflation and real exchange rate volatility on private

investment using panel data for developing countries. The same result is obtained by Cardoso (1993) and Larrain and Vergara (1993) on panel data for Latin American and East Asian developing countries, respectively.

Hausmann and Gavin (1995) likewise report a negative association between an index of macroeconomic volatility -- which combines real GDP and real exchange rate volatility -- and the investment/GDP ratio, using a large sample of developing countries. By contrast, Bleaney (1996), using 1980s averages for some 40 developing countries, finds only weak evidence that standard measures of macro instability (average inflation, the fiscal balance, the variability of the real exchange rate) affect *aggregate* investment; instead, in his sample such instability measures seem to have a direct impact on growth -- which appears to suggest that they reflect on the *quality* of investment.

Similarly, Aizenman and Marion (1995) report a negative correlation between indicators of economic instability (such as the volatility of the terms of trade, inflation and the real exchange rate) and private investment, using averaged data on 47 developing countries for the period 1970-92. They further show that these volatility measures contribute significantly to explain the performance of private investment in a regression framework.

Finally, recent work by Ghosal and Loungani (1996) focuses on the impact of price uncertainty on investment using panel data for US manufacturing industries. For those subsectors with a high degree of product market competition, they find a large negative and significant effect of price volatility on sectoral investment.

### ***Political and social instability***

The above discussion has focused on the investment impact of uncertainty as reflected by the volatility of macroeconomic variables. However, there is a parallel empirical literature -- based almost invariably on reduced-form specifications -- concerned with the effects of political instability on investment.

Under this heading we can include a broad range of issues, from political instability understood as rapid government turnover -- which can lead to an unstable incentive and policy framework, thus raising the value of waiting and discouraging investment -- to

more extreme forms of social and political unrest that create a more fundamental kind of uncertainty for investors by threatening their property rights. This applies in particular to political events involving a redefinition of the basic "rules of the game", especially when they raise the risk of expropriation (like in Egypt in the 1950s or Nicaragua in the 1980s).

From the investment viewpoint, the effective enforcement of property rights is at least as important as their formal definition. For example, the lack of impartial mechanisms to resolve contractual disputes makes the returns to investment more difficult to predict, as the practical validity of contracts becomes uncertain. Recent work by Knack and Keefer (1995) using cross-country data shows that indicators of property rights enforcement (such as the perceived risk of expropriation and the repudiation of contracts by the government) are strongly associated with private investment performance. Indeed, once such factors are taken into consideration, Knack and Keefer show that conventional indicators of political instability and social unrest do not contribute significantly to explain the cross-country performance of private investment.

A likely important source of social tension and political conflict is income inequality. A recent literature has investigated the relationship between measures of income distribution and private investment performance. Using data for industrial countries, Persson and Tabellini (1992) find a positive and marginally significant correlation between equality in income distribution and investment/GDP ratios, although they do not identify the particular mechanism responsible for this association. More recently, Alesina and Perotti (1995) have revisited this issue. Using cross-country data, they find that income inequality raises political instability, which in turn hampers investment. Once political instability is controlled for, inequality has no independent effect on investment, which suggests that inequality tends to deter investment by threatening property rights, in line with the other results summarized above.

### ***Policy implications***

The general message from this analytical and empirical literature is that, from the viewpoint of investment, the stability and predictability of the incentive framework -- relative prices, demand, interest rates, taxes -- may be much more important than the *level*

of the incentives themselves. This view has important consequences for macroeconomic policy-making in developing countries in general, and for the design of reform programs in particular.

From the macroeconomic viewpoint, the key policy implication is that to encourage the investment response to incentive changes macroeconomic stability and investor confidence in the sustainability of the policy framework are essential. Thus, governments should correct unsustainable macroeconomic imbalances -- such as high inflation, large public deficits and exchange rate overvaluation -- because they are a primary cause of macroeconomic instability and uncertainty about future policies. Institutional reforms ensuring policy predictability, effective property rights, and stability of the basic ‘rules of the game’ can also contribute to facilitate significantly the investment response to incentive changes.

It is less clear, however, how to address the externality that may arise from the interaction of the option to wait and imperfect credibility, which could hamper the response to an economic reform program and leave the economy stuck in a self-fulfilling low investment equilibrium. The externality would seem to demand some kind of policy intervention -- e.g., investment tax incentives. But such a measure could easily backfire, because it would almost certainly send the wrong signal to investors -- that fiscal irresponsibility and tax uncertainty continue to rule. Other external interventions to reassure investor confidence -- like the provision of sufficient external finance, or the resolution of a debt overhang -- are likely to be much more effective in this regard.

In concluding this section, two important qualifications should be made concerning much of the empirical literature on the uncertainty-investment link -- specifically, those studies that uncover a *long-run* negative association between both variables. As argued earlier, their relation to irreversibility is not entirely clear, since no such long-run impact follows from the theoretical literature. Their findings therefore suggest that other forces -- e.g., investor risk aversion in a context where the ability to diversify risks is limited -- may be at work in the data.

Second, many of these reduced-form empirical results are based on sample measures of variability -- typically, variances or standard deviations of relevant variables -



- which suffer from two shortcomings. First, variability does not necessarily amount to uncertainty, except when events are unpredictable; in theory, more accurate measures of uncertainty would be provided by, e.g., the variances of the *innovations* to the variables of interest. Second, sample measures of volatility fail to reflect uncertainty of the ‘peso problem’ variety, concerning agents’ expectations about events not observed in the sample. Yet this kind of uncertainty -- like, for example, subjective anticipations of a policy reversal -- can be critical, as illustrated by the discussion of credibility in the preceding section. In this regard, variables that measure to some degree the sustainability of economic policies -- the parallel market premium, the fiscal deficit, the debt burden -- can also provide useful information about the uncertainty perceived by investors.

#### **4. Uncertainty and investment: some implications for Africa**

Concern with Africa’s disappointing growth performance over the last two decades has prompted renewed interest in its causes and possible remedies (see e.g., World Bank 1994). With fixed investment regarded virtually unanimously as one of the key ingredients for growth (see Levine and Renelt 1992 and Schmidt-Hebbel, Sérven and Solimano 1996), the evolution of investment in Sub-Saharan Africa obviously deserves closer scrutiny.

Table 1 presents indicators of investment performance across developing regions for the 1970s and 1980s, drawing from World Bank data for 86 developing countries, of which 40 belong to Sub-Saharan Africa; both private investment and total investment as ratios to real GDP are reported.<sup>18</sup> As the table shows, Sub-Saharan Africa lags behind other developing regions along both dimensions, with the only exception of South Asia, that presents roughly similar indicators. Both regions are very far from the investment ratios of the successful East-Asian economies. This is particularly striking in the case of private investment, which in the 1980s amounted in Africa to less than half the level observed in East Asia.

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<sup>18</sup> Whenever possible, private investment data exclude the investment of public enterprises, drawing from Jaspersen, Aylward and Sumlinski (1995). However, this information is not available for every country in the sample, and therefore some heterogeneity in this dimension is likely to be present in our data.

Table 1 suggests that private investment ratios changed little in Africa over 1970-90. While this is true for decade averages, private investment did indeed display some fluctuation during that period. As Figure 3 shows, private investment followed a rising trend relative to GDP until the early 1980s, which was reversed after 1982 (public investment, not shown in the figure, displays a similar, if somewhat more marked, pattern). The figure also shows that this cycle of boom-bust was qualitatively similar to -- although quantitatively more modest than -- those witnessed in other developing regions<sup>19</sup> (e.g., the Latin America and Other LDC regions in the graph).

### *Empirical evidence*

Africa's weak private investment performance has been the focus of several recent empirical studies. These studies highlight the role of uncertainty and instability as investment deterrents, after controlling for various other investment determinants. Hadjimichael and Ghura (1995) analyze empirically the private investment performance of 32 African countries over the period 1986-1992, using a specification that includes the variabilities of inflation and the real exchange rate as measures of macroeconomic uncertainty, and an index of political and civil liberties as proxy for the definition of property rights. Their estimation results show that either measure of macroeconomic uncertainty has a strong adverse impact on investment, while the political variable has a positive but insignificant effect.<sup>20</sup>

These results are in agreement with those reported by Ghura and Grennes (1993) in their study of macroeconomic performance in 33 Sub-Saharan African countries during 1972-1987. They find that real exchange rate volatility (measured by the coefficient of variation) has a strong adverse impact on the (total) investment/GDP ratio. In turn, the black market premium, which is taken in the study as a measure of real exchange rate misalignment, also has a significant negative effect on investment.

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<sup>19</sup> This boom-bust investment cycle in developing countries is analyzed in Sérvén and Solimano (1993a).

<sup>20</sup> See also Hadjimichael *et. al.*, 1995.

Another recent study by Kumar and Mlambo (1995) provides a comprehensive empirical investigation of the determinants of private investment in 40 Sub-Saharan African countries over 1970-1993. The paper's encompassing framework includes variables measuring macroeconomic instability -- proxied by the inflation rate and the variability of the fiscal deficit and the terms of trade -- as well as measures of restrictions on political and civil liberties, which the authors view as proxies for political instability. Their results indicate a consistently strong and negative impact of inflation, while the other two proxies for macroeconomic instability also carry the expected negative sign but only become statistically significant after 1980. In turn, the two political indicators have also the expected negative signs, although on the whole the measure of civil liberties appears to exert a stronger impact on investment than the measure of political rights.

Since these studies explore at length the empirical link between instability and investment in Africa, a comparative perspective could provide a useful complement to their analyses. With this objective (and subject to the caveats expressed earlier about the use of sample measures of uncertainty), Table 2 presents some regional indicators of economic instability: inflation, the black market premium, and the variabilities of these two variables plus those of the real exchange rate and the terms of trade.<sup>21</sup>

It is important to clarify how these variabilities are measured. In the case of the terms of trade and the real exchange rate, for each country and year we calculate the coefficient of variation of the relevant variable over a three-year horizon (i.e., the current plus the previous two years). For inflation and the black market premium, we follow the same procedure but compute the standard deviation rather than the coefficient of variation.<sup>22</sup> This provides a time series for each country (notice we lose the first two annual observations); we then compute country averages for the subperiods presented in Table 2.

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<sup>21</sup> To limit the impact of outliers, we transformed both inflation and the black market premium to  $x/(1+x)$ , where  $x$  is the variable as originally measured.

<sup>22</sup> The coefficient of variation is not appropriate for inflation and the black market premium because at very low inflation (or very low premium) the coefficient of variation would become extremely large. In turn, for the terms of trade and the real exchange rate we did compute also standard deviations, which led to regional rankings similar to those in Table 2.

The most striking fact in Table 2 is perhaps the clearly superior performance of East Asia and, to some extent, also South Asia, along all dimensions of economic instability, not only in the policy-related ones (inflation, black market premium and real exchange rate) but even in the more “chance-related” terms of trade.

Concerning Africa, the table also reveals a number of interesting facts. First, in terms of both average inflation and inflation volatility, Sub-Saharan Africa is above other LDC regions -- with the obvious exception of Latin America -- and, in particular, far from the low levels of East Asia, especially in the 1980s. Second, black market premia are high in Africa, but -- at least over the time period considered here -- not as high as in other developing regions, excluding of course East Asia. Third, variability of the parallel market premium is relatively moderate in Sub-Saharan Africa, once account is taken of a few outlying observations (notably Ghana in the 1980s). Fourth, Africa is at or near the top in terms of real exchange rate and terms-of-trade variability -- with the latter fact likely reflecting the poorly diversified structure of Africa’s foreign trade.

To complement these indicators of macroeconomic instability, Table 3 presents eleven measures of socio-political instability and institutional quality. The first seven variables in the table (assassinations, coups, constitutional changes, government crises, riots, revolutions and cabinet changes) measure different forms of civil unrest and political instability, and are commonly used in the political economy literature<sup>23</sup>. The eighth is a dummy variable that for each country takes the value of one in those years when the country in question is involved in a war (civil or international). The ninth is an index of restrictions on civil liberties, taken from Barro and Lee (1994), and used in the investment study by Kumar and Mlambo (1995). The tenth variable is the ethnic division indicator examined by Easterly and Levine (1996) in their comparative analysis of growth in Africa; it can be viewed as an indicator of underlying social tensions. Finally, the last variable is an indicator of property rights, taken from Knack and Keefer (1995),<sup>24</sup> unlike with all the

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<sup>23</sup> The primary source is Banks (1994).

other variables, in this case a higher value represents a *better* score. All the variables shown in the table are available annually, with the exception of the last two. Since the information is in all cases qualitative, outlying observations are less of a concern than in the case of the economic instability indicators above, and thus to keep the table manageable only the regional means are presented.

According to the figures in Table 3, Sub-Saharan Africa presents a mixed report card. Relative to other regions, she scores relatively well in some civil unrest indicators (assassinations, government crises and riots), badly in others (coups and constitutional changes) and places at the middle in the rest. This mixed outcome, however, might reflect in part weaknesses of these civil unrest measures, which are largely compiled from international press reports whose coverage may not be balanced across world regions.

Turning to the remaining variables in the table, Africa has the worst score in terms the civil liberties indicator, and the second-worst in terms of ethnic division. Finally, the property rights and frequency of war indicators rank Africa at the middle.

What does all this imply from the point of view of private investment ? A preliminary assessment can be given by examining the correlations of these indicators with investment ratios. This is done in Table 4 for the economic instability variables, and in Tables 5 and 6 for the political and institutional variables; in addition, the tables also present the cross-correlations between the different indicators.

To assess the possible impact of outliers, Table 4 presents both simple correlations (top half of the table) and Spearman rank correlations (bottom half); the latter are robust to extreme observations. The results in the table confirm the strong negative association between private investment and economic instability reported by the empirical literature: all the correlations with investment are negative and significant at the 1 percent level, with the only exception of the rank correlation with inflation, which is not significant. Moreover, the different indicators do not appear strongly correlated with each other, with

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<sup>24</sup> It represents a combined assessment of three factors affecting the definition of property rights: government repudiation of contracts, expropriation risk, and the rule of law. A higher value means more certainty about property rights.

the main exceptions of inflation and its variability, and the parallel market premium and its variability.

Table 5 presents analogous information for the political and institutional variables on which annual information is available.<sup>25</sup> The most striking result is the strong negative correlation of investment with the measure of restrictions on civil liberties, which is large and extremely significant. The war dummy likewise displays a significant negative association with the private investment ratio. Regarding the civil unrest variables, two of them (revolutions and cabinet changes) consistently show a negative and significant correlation with investment, and the remaining five appear uncorrelated with the private investment ratio.

Finally, Table 6 presents similar information for the two socio-political indicators lacking annual information. Their cross-sectional correlations with private investment have the expected signs -- deeper ethnic division and weaker property rights are associated with lower investment -- but on the whole their precision is not high (they are significant at the 10 percent level only), likely reflecting the much smaller sample size.

On the whole, the above results do bring out a negative association between private investment performance and measures of economic and political instability and institutional weakness. However, these are just bivariate correlations, and one may wonder to what extent economic and political instability continues to be negatively associated with private investment once other standard investment determinants are taken into consideration.

While a thorough empirical assessment of the determinants of private investment across the world is well beyond the scope of this paper, Table 7 presents some preliminary estimation results using conventional reduced-form investment equations to which measures of instability have been added as regressors. The basic specification is comparable to those considered in the recent empirical studies of investment in Africa just mentioned, but the panel data sample used here covers other developing regions as well.

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<sup>25</sup> Notice that there is a potential sample selection problem here. At times of acute political conflict (e.g., wars), information on investment and other economic variables may be unavailable. If, as seems plausible, investment is lower in those situations, its negative association with measures of political conflict will be understated by the available data.

Data limitations are substantial and deserve explicit consideration. First, the availability of data on the various regressors differs across countries and years, and therefore the panel data set is unbalanced. Second, the samples for which all regressors are available are substantially smaller than those used in the bivariate correlations above. This is especially problematic regarding interest rate data, which were unavailable for a large number of countries; thus, we present regression results both with and without interest rates. Table 7 reports GLS random effects estimates; while fixed effect specifications were also estimated, Hausman tests (shown at the bottom of the table) could not reject the validity of the asymptotically-efficient GLS estimates.

In addition to the institutional and instability indicators, the empirical specifications include several standard regressors: real per-capita GDP, real GDP growth, public investment, real domestic credit growth (alternatively, the real ex-post interest rate), the terms of trade, the fiscal surplus, and the external debt/GDP ratio. This set of regressors is similar to those encountered in the cross-country investment studies mentioned earlier.

The first two columns of Table 7 exclude interest rates. The estimation results show that among conventional investment determinants, real per-capita GDP and the public investment ratio have a positive and significant impact on private investment. The latter result agrees with the findings of Hadjimichael and Ghura 1995 and Kumar and Mlambo 1995, and suggests complementarity between private and public projects in the sample. Somewhat surprisingly, the terms of trade has a negative and highly significant impact on private investment -- a result also found by Kumar and Mlambo (1995) which suggests that trade windfalls lead to consumption, not investment, booms, and/or favor the expansion of labor-intensive, rather than capital-intensive, economic activities.

The estimation results show no appreciable effect of domestic credit growth on investment. In turn, the fiscal surplus has a strongly favorable impact on private investment, in accordance with previous studies, while exactly the reverse is true for the external debt/GDP ratio; both parameters are highly significant. By contrast, the inflation rate and the black market premium have no significant effect.

The next four regressors are the economic instability measures examined above -- the variabilities of the terms of trade, inflation, the black market premium and the real

exchange rate. In column 1, the first two are found to have a significant adverse impact on private investment.

The final set of regressors in Table 7 are the political/institutional indicators on which information is available annually. In column 1, which excludes the civil unrest variables, both the war dummy and the indicator of restrictions on civil liberties have a significantly negative impact on investment.

Column 2 adds the seven indicators of civil unrest to the empirical specification. This results in the loss of some 50 observations for which such indicators are unavailable. Only the variable measuring cabinet changes turns out significant (at the 10 percent level); it carries a negative sign, as expected. In turn, the estimates and standard errors of the remaining parameters show little change, with the exceptions of the black market premium and the war dummy -- whose coefficients become substantially larger (in absolute value) and more significant.

Columns 3 and 4 replace the domestic credit variable with the real ex-post interest rate. Unfortunately, this causes the loss of nearly 50 percent of the sample observations, which in turn leads to a general loss of precision. In column 3, which excludes the civil unrest indicators, the real interest rate itself carries a significant negative coefficient, as should be expected. Public investment and the black market premium become insignificant and, among the economic instability indicators, only the terms of trade retains significance in the reduced sample. The estimated coefficient on the civil liberties indicator is similar to that in columns 1 and 2, but it is now insignificant. By contrast, the war dummy remains strongly significant.

Finally, column 4 adds again the civil unrest variables, leading to the loss of another 40 observations (and a further loss of precision). None of the civil unrest indicators is statistically significant, and in addition the real interest rate and the fiscal surplus become insignificant. The black market premium, however, now carries a significantly (at the 10 percent level) negative coefficient. Among the other instability indicators, the terms of trade variability and the war dummy retain their significant negative association with private investment.



The above results are admittedly very preliminary and, due to their reduced-form framework, cannot be strictly viewed as identifying causation (rather than simple association) between variables. Nevertheless, the estimates do indicate that fiscal imbalances, high external debt, inflation variability, black market premia and terms of trade volatility are significantly associated with a worsened private investment performance, after controlling for standard investment determinants. Likewise, the regressions show a strong negative association between extreme sociopolitical conflict in the form of war and private investment. Finally, at least in the larger sample considered above, the results also provide evidence that government instability (as measured by the frequency of cabinet changes) and tighter restrictions on civil liberties are significantly associated with lower private investment ratios.<sup>26</sup> Thus, on the whole the multivariate regression results appear consistent with the bivariate correlations examined earlier.

To conclude this section, what are the policy implications for Africa of the empirical evidence reviewed here ? In a medium-term perspective, the resumption of growth will undoubtedly require an increase in investment ratios, which will have to come primarily from the private sector. But in spite of the modest achievements of the reform programs initiated in the late 1980s, macroeconomic instability -- high fiscal deficits, inflation, real exchange rate overvaluation -- remains a concern in many African countries (World Bank, 1994). Both the analytical discussion in the previous sections and the empirical evidence above suggest that the region has much to gain in terms of investment from further progress in the reduction of macroeconomic imbalances and macroeconomic volatility. Establishing a sustainable fiscal position, consistent with low and predictable inflation, emerges as a major priority. In addition, at a more fundamental level, institutional reforms protecting property rights and fostering social consensus may be a promising avenue.

In other areas the implications are less clear-cut. What can be done about the volatility of the terms of trade, which is higher in Africa than in other regions ? The

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<sup>26</sup> It is debatable, however, whether the civil liberties indicator is capturing underlying sociopolitical tensions (as assumed by Kumar and Mlambo, 1995) or rather the quality of the overall institutional framework.

obvious answer is of course to achieve a more diversified export base, but this cannot be done overnight. And what about the external debt burden ? The regressions suggest that it may pose a significant obstacle for investment resumption in a number of countries -- not only because of the drain on investible resources that debt service implies, but possibly also due to the adverse effect that the perceived debt overhang may have on the credibility of the reform efforts. The implication is that Africa may need a substantial reduction in her debt burden to set investment and growth in motion. Indeed, the international community has started moving in this direction.

## 5. Concluding remarks

This paper has reviewed a recent investment literature that highlights the option value of waiting. When there is uncertainty and investment projects are irreversible, waiting for more information has a value because it can help avoid costly mistakes, should the projects be revealed as unprofitable due to adverse events. The literature shows that the value of waiting can be extremely high even with moderate uncertainty. Thus, the latter becomes a powerful investment deterrent even under strict risk-neutrality. The key implication is that, to encourage investment, the stability and predictability of the incentive framework -- relative prices, demand, interest rates, taxes -- may be much more important than the *level* of the incentives themselves. To put it differently, *huge* incentives may be necessary for investors to give up their option to wait and commit themselves to irreversible investment in an uncertain environment.

The central implication for macroeconomic policy is that, to encourage investment and facilitate its response to incentive changes, governments should attach top priority to correction of unsustainable macroeconomic imbalances -- such as high inflation, large public deficits and exchange rate overvaluation -- which are a primary cause of macroeconomic instability and uncertainty about future policies. Institutional reforms to reduce social tensions and ensure the enforcement of property rights can also go a long way to facilitate the response of investment to incentive changes.

The paper has also examined the practical relevance of the uncertainty-investment link for developing countries in general and Sub-Saharan Africa in particular. Using a

cross-country perspective, the comparative evidence reveals that Sub-Saharan Africa stands out for the volatility of her terms of trade and real exchange rates, and for her poor indicators in terms of property rights and civil liberties. Based on a large sample of developing country data, the paper has shown that these and other indicators of instability and institutional quality are negatively related to private investment. The implication is that Sub-Saharan Africa may have much to gain from progress in reducing economic and political instability and improving her institutions.

In concluding, while the irreversibility approach brings out a number of relevant policy implications, it is important to be aware also of its limitations. Three of them are worth mentioning here. First, on theoretical grounds irreversibility cannot explain the negative *long-term* association between instability (whether economic or political) and investment performance found by a number of empirical studies. While such relation might arise under particular conditions, it is by no means a general consequence of investment irreversibility, and likely reflects the simultaneous action of other factors, such as investor risk aversion and limited access to risk diversification.

Second, from an analytical perspective, irreversible investment is only one of the factors that can render investment decisions insensitive to changes in incentives. Other reasons, such as liquidity constraints (Hubbard 1994) or fixed costs (Caballero and Leahy 1996) can likewise create a “range of inaction” for investment, in which firms fail to tune their investment decisions to changing profitability conditions.

Third, and most important, the irreversibility approach only describes investors’ decisions about when (or whether) to adopt profitable investment projects (or exercise their investment “options”). At least equally important from the policy viewpoint is the question of how these profitable investment opportunities arise in the first place. Specifically, in the context of Sub-Saharan Africa, what are the key policies that would help generate valuable investment options ? The right answer surely varies across countries, but investment in human capital, adequate infrastructure provision and effective institutions fostering property rights and social consensus would undoubtedly be at the top of the priority list.

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Table 1

**Investment / GDP ratios in developing regions**  
(percent at constant prices)

	<u>1970-79</u>	<u>1980-90</u>	<u>1970-90</u>
<b>1. Private investment</b>			
Sub-Saharan Africa	8.19	8.27	8.66
Latin America	14.64	12.05	13.22
South Asia	7.14	10.01	8.29
East Asia	17.16	17.42	17.28
Other LDCs	9.64	11.43	11.07
<b>2. Total investment</b>			
Sub-Saharan Africa	17.45	17.72	17.45
Latin America	24.07	19.03	21.12
South Asia	13.21	17.61	17.39
East Asia	25.45	29.42	27.35
Other LDCs	23.49	24.85	23.18

Notes: the figures correspond to the regional median of individual country averages over the respective periods.

The country groups are defined as follows:

1. Sub-Saharan Africa (40 countries):

Angola, Benin, Burundi, Cameroon, Cape Verde, Central Africa Republic, Chad, Congo, Cote d'Ivoire, Djibouti, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea-Bissau, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Namibia, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zaire, Zambia and Zimbabwe.

2. Latin America (19 countries):

Argentina, Bolivia, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Panama, Paraguay, Peru, Uruguay, Venezuela.

3. South Asia (5 countries):

Bangladesh, India, Nepal, Pakistan, Sri Lanka.

4. East Asia (7 countries):

Indonesia, Korea, Malaysia, Papua New Guinea, Philippines, Singapore, Thailand.

5. Other LDCs (13 countries):

Algeria, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Morocco, Oman, Syrian Arab Rep., Tunisia, Turkey, United Arab Emirates.

Source: World Bank data.



**Table 2**  
**Regional Indicators of Economic Instability**

	Inflation		Inflation Variability <sup>a/</sup>		Black Market Premium		Black Market Premium Variability <sup>a/</sup>		Real Exchange Rate Variability <sup>b/</sup>		Terms of Trade Variability <sup>b/</sup>	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
<b>1. 1970-79</b>												
Sub-Saharan Africa	10.44	9.20	5.98	5.46	15.70	5.22	19.81	7.96	7.78	6.65	13.47	10.25
Latin America	15.37	9.46	16.04	5.74	11.88	12.26	17.30	4.76	7.01	4.29	12.71	9.79
South Asia	7.42	6.63	6.39	6.43	28.88	27.31	25.20	22.45	11.13	5.90	10.15	8.22
East Asia	9.19	8.01	6.42	6.35	5.05	1.79	4.95	1.88	6.85	4.90	9.92	8.80
Other LDCs	9.19	8.08	3.67	3.64	14.27	11.52	8.56	9.33	5.72	5.05	14.28	9.30
<b>2. 1980-90</b>												
Sub-Saharan Africa	13.25	10.09	9.55	5.38	20.30	10.67	53.80	9.89	12.14	9.15	9.05	6.78
Latin America	24.16	17.88	153.96	9.09	25.18	26.08	40.72	25.10	10.53	7.40	8.01	5.96
South Asia	8.63	8.31	3.05	2.38	21.60	14.21	16.11	13.54	4.53	3.35	5.76	4.46
East Asia	6.47	5.97	3.49	2.59	2.44	2.13	4.46	3.56	5.75	5.08	5.99	5.14
Other LDCs	11.55	7.84	5.39	3.52	31.39	7.52	63.35	15.99	10.75	8.33	11.29	7.23
<b>3. 1970-90</b>												
Sub-Saharan Africa	11.99	9.32	8.58	5.56	18.11	11.32	38.52	9.11	10.30	7.77	10.91	8.21
Latin America	19.97	13.84	95.89	7.60	18.85	18.44	30.86	25.46	9.05	5.39	9.99	7.42
South Asia	8.00	8.24	4.03	4.93	25.07	19.37	19.94	18.27	7.31	3.82	7.61	5.13
East Asia	7.75	6.83	4.69	4.09	3.69	2.19	4.66	2.79	6.21	5.01	7.64	6.29
Other LDCs	10.05	8.15	4.37	2.99	23.24	11.89	40.28	13.71	8.63	5.88	12.54	8.55

Notes: <sup>a/</sup> For each region and period the figures reflect the mean (or median) of the respective countries' time-varying standard deviation, computed in each year using the current and the two lagged observations of the variable in question.

<sup>b/</sup> For each region and period the figures reflect the mean (or median) of the respective countries' time-varying coefficient of variation, computed in each year using the current and the two lagged observations of the variable in question.

**Table 3**

**Regional Indicators of Socio-Political Instability and Institutional Quality**  
(1970-90 Averages)

	<u>Assassinations</u>	<u>Coups d'etat</u>	<u>Constitutional Changes</u>	<u>Government Crises</u>	<u>Riots</u>	<u>Revolutions</u>	<u>Cabinet Changes</u>	<u>War</u>	<u>Restrictions on Civil Liberties</u>	<u>Ethnic Division</u>	<u>Property Rights</u>
<u>Region</u>											
Sub-Saharan Africa	6.77	4.45	13.10	7.00	27.91	22.09	41.24	14.88	5.47	65.46	3.47
Latin America	75.44	5.54	8.03	25.81	43.61	21.80	44.87	13.68	3.60	26.63	3.32
South Asia	35.92	5.32	15.96	23.30	307.78	20.39	59.57	21.00	4.01	67.50	4.18
East Asia	25.00	3.12	10.94	17.14	82.14	31.43	42.97	19.28	4.23	53.14	4.60
Other LDCs	26.14	1.22	6.94	17.42	38.26	15.91	38.77	8.57	5.46	24.00	3.31

Note: For variable definitions, see text.

Table 4

Correlation Between Private Investment and Economic Instability Indicators<sup>a/</sup>

## 1. Simple correlation

	Private Investment/ GDP Ratio	Inflation	Inflation Variability	Black Market Premium	Black Market Premium Variability	Real Exchange Rate Variability	Terms of Trade Variability
Private Investment/ GDP Ratio	1	-0.0855 (0.0261)	-0.0558 (0.0276)	-0.1185 (0.0263)	-0.1086 (0.0276)	-0.0708 (0.0279)	-0.1409 (0.0249)
Inflation		1	0.3002 (0.0276)	0.2712 (0.0276)	0.2642 (0.0289)	0.32 (0.0291)	0.0516 (0.0273)
Inflation Variability			1	0.0381 (0.0291)	0.0674 (0.0291)	0.0771 (0.0293)	0.0254 (0.0276)
Black Market Premium				1	0.4177 (0.0276)	0.1868 (0.029)	0.1542 (0.0276)
Black Market Premium Variability					1	0.1899 (0.029)	0.0663 (0.0276)
Real Exchange Rate Variability						1	0.0277 (0.0279)
Terms of Trade Variability							1
Civil Liberties							

## 2. Rank correlation

	Private Investment/ GDP Ratio	Inflation	Inflation Variability	Black Market Premium	Black Market Premium Variability	Real Exchange Rate Variability	Terms of Trade Variability
Private Investment/ GDP Ratio	1	-0.0162 (0.0261)	-0.1305 (0.0276)	-0.1020 (0.0263)	-0.1680 (0.0276)	-0.1490 (0.0279)	-0.1171 (0.0249)
Inflation		1	0.5483 (0.0276)	0.2718 (0.0276)	0.3346 (0.0289)	0.2927 (0.0291)	0.1041 (0.0273)
Inflation Variability			1	0.2215 (0.0292)	0.2753 (0.0291)	0.3345 (0.0293)	0.1197 (0.0276)
Black Market Premium				1	0.7516 (0.0276)	0.0841 (0.0290)	0.0830 (0.0276)
Black Market Premium Variability					1	0.1703 (0.0290)	0.0906 (0.0276)
Real Exchange Rate Variability						1	0.0113 (0.0279)
Terms of Trade Variability							1
Civil Liberties							

Note: <sup>a/</sup> The correlations are computed using both the time-series and cross-country variation of each variable. Standard errors in parentheses.

Table 5

**Correlation Between Private Investment and Socio-Political Indicators<sup>a/</sup>**

	Private Investment/ GDP Ratio	Assassinations	Coups d'etat	Constitutional Change	Government Crises	Riots	Revolutions	Cabinet Changes	War	Restrictions on Civil Liberties
Private Investment/ GDP Ratio	1	0.0073 (0.0239)	-0.0388 (0.0251)	-0.052 (0.0251)	-0.001 (0.0239)	0.0245 (0.0239)	-0.0916 (0.0239)	-0.0797 (0.0251)	-0.0503 (0.0250)	-0.2029 (0.0265)
Assassinations		1	0.576 (0.0252)	0.0299 (0.0252)	0.1877 (0.0239)	0.1574 (0.0239)	0.2082 (0.0239)	0.0905 (0.0252)	0.2830 (0.0254)	-0.0599 (0.0266)
Coups d'etat			1	0.3844 (0.0251)	0.2264 (0.0252)	0.0234 (0.0252)	0.3761 (0.0252)	0.2792 (0.0251)	0.0751 (0.0260)	0.0036 (0.0281)
Constitutional Change				1	0.1224 (0.0252)	0.0309 (0.0252)	0.1908 (0.0252)	0.2369 (0.0251)	0.0885 (0.0260)	0.0216 (0.0281)
Government Crises					1	0.1777 (0.0239)	0.2764 (0.0239)	0.2430 (0.0252)	0.0630 (0.0254)	-0.0959 (0.0266)
Riots						1	0.0558 (0.0239)	0.1307 (0.0252)	0.1615 (0.0254)	-0.1538 (0.0266)
Revolutions							1	0.2561 (0.0252)	0.3704 (0.0254)	0.0665 (0.0266)
Cabinet Changes								1	-0.0036 (0.0260)	-0.0442 (0.0281)
War									1	0.0217 (0.0281)
Restrictions on Civil Liberties										1

Note: <sup>a/</sup> The correlations are computed using both the time-series and cross-country variation of each variable. Standard errors in parentheses.

**Table 6**  
**Cross-Country Correlation Between Private Investment and**  
**Institutional/Political Indicators**<sup>a/</sup>

	Private Investment/ GDP Ratio	Ethnic Division	Property Rights
Private Investment/GDP Ratio	1	-0.1623 (0.1179)	0.2261 (0.1231)
Ethnic Division		1	0.0193 (0.125)
Property Rights			1

<sup>a/</sup> Correlations between the 1970-90 country averages of the corresponding variables.  
Standard errors in parentheses.

42  
Table 7

GLS panel estimates  
(dependent variable: private investment/GDP)

	1	2	3	4
Constant	14.235*** (1.427)	14.492*** (1.563)	14.770*** (2.077)	14.993*** (2.339)
Real GDP per capita	0.001*** (0.000)	0.001** (0.000)	0.004*** (0.001)	0.004*** (0.001)
GDP growth	0.021 (0.023)	0.018 (0.023)	0.030 (0.032)	0.033 (0.033)
Public investment/GDP	0.058* (0.031)	0.057* (0.032)	-0.011 (0.038)	-0.002 (0.040)
Terms of trade	-1.430*** (0.503)	-1.312** (0.520)	-1.806** (0.862)	-2.115** (0.936)
Real interest rate	---	---	-5.951* (3.172)	-5.168 (3.461)
Domestic credit growth	-0.000 (0.000)	-0.000 (0.001)	---	---
Public sector balance/GDP	0.125*** (0.034)	0.113*** (0.036)	0.072* (0.040)	0.063 (0.044)
External debt/GDP	-0.033*** (0.006)	-0.033*** (0.007)	-0.045*** (0.009)	-0.042*** (0.010)
Inflation rate	1.218 (1.379)	1.646 (1.463)	-4.510 (3.576)	-3.459 (3.975)
Black market premium	-1.221 (0.894)	-1.707* (0.943)	-1.677 (1.341)	-2.723* (1.472)
Terms of trade variability	-3.203* (1.705)	-3.066* (1.742)	-5.067** (2.364)	-5.007** (2.472)
Inflation variability	-0.001*** (0.000)	-0.001*** (0.000)	-0.000 (0.000)	-0.000 (0.000)
Black market premium variability	-0.000 (0.001)	-0.001 (0.001)	0.000 (0.001)	0.000 (0.001)
Real exchange rate variability	1.336 (1.854)	1.368 (1.938)	0.529 (2.237)	0.350 (2.407)
Restrictions on civil liberties	-0.330** (0.168)	-0.344* (0.183)	-0.353 (0.230)	-0.333 (0.257)
War	-1.046** (0.501)	-1.448*** (0.540)	-1.541** (0.735)	-1.750** (0.820)
Assassinations	---	0.105 (0.094)	---	0.089 (0.127)
Coups d'etat	---	1.006 (0.760)	---	1.280 (1.093)
Constitutional Changes	---	-0.366 (0.464)	---	-0.149 (0.606)
Cabinet Changes	---	-0.507* (0.275)	---	-0.015 (0.375)
Government Crises	---	-0.332 (0.331)	---	0.235 (0.473)
Riots	---	0.060 (0.084)	---	-0.049 (0.123)
Revolutions	---	0.572 (0.366)	---	0.588 (0.520)
F statistic (p-value)	0.000	0.000	0.000	0.000
LM error components test (p-value)	0.000	0.000	0.000	0.000
Hausman test (p-value)	0.707	0.991	0.996	0.999
Number of observations	857	806	476	436

Note: the symbols \*, \*\*, and \*\*\* respectively denote significance at the 10%, 5% and 1% levels.

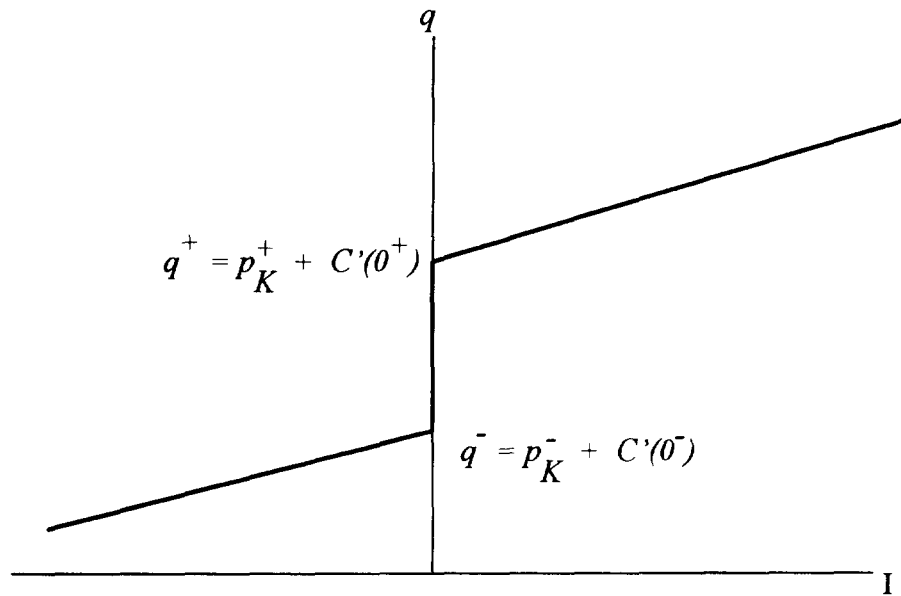
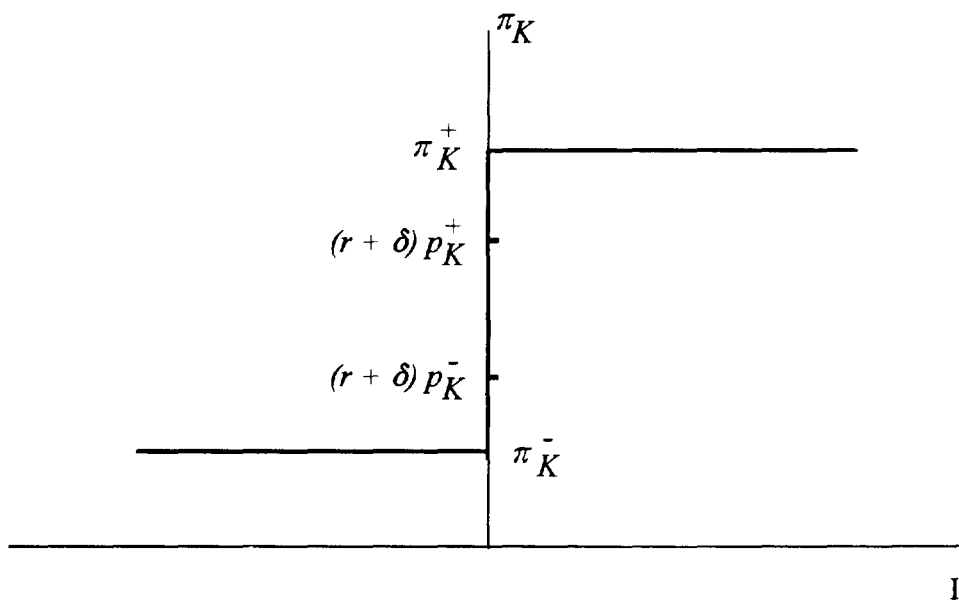
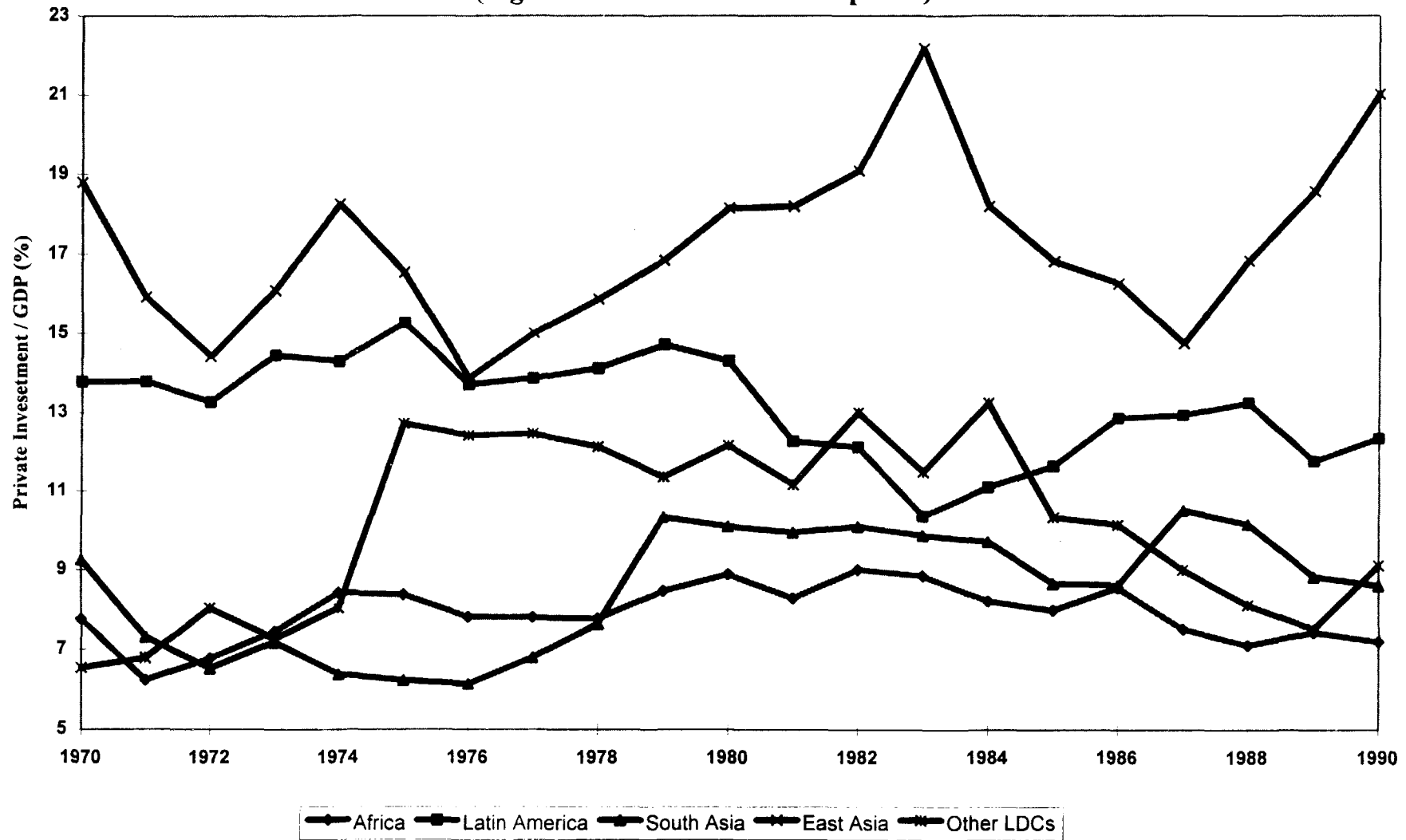
**Figure 1****Investment with costly reversibility****Figure 2****Investment with linear adjustment costs**

Figure 3

**Private Investment / GDP Ratios in Developing Regions**  
(regional medians at constant prices)









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